Built Asset Management Climate Change Adaptation Model

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Abstract

Purpose - Climate change continues to pose major challenges to those responsible for the management of built assets. The adaptation required to address long-term building performance affected by climate change rarely get prioritised above more immediate, short-term needs (general built asset management needs). This paper, thus presents results of an action research addressing climate change adaptation of selected social housing stock in the UK.

Design /methodology/approach – The study adopts an in-depth participatory action research with a London based social landlord and integrates climate change adaptation framework and performance based model established through author's previous research projects.

Findings - A staged process for including adaptation measures in built asset management strategy is developed along with metrics to analyse the performance of the housing stock against climate change impacts of flooding. The prioritisation of adaptation measure implementation into long term built asset management plans was examined through cost based appraisal.

Research Limitation – The research was carried out with a singular organisation, already acquainted with potential climate change impacts, vulnerability and adaptive capacity assessment. The process adopted will differ for similar organisation in the sector with different settings and limited working knowledge of climate change impact assessment.

Originality /Value –. In addition to the practical results from the study the paper outlines a novel process that integrates resilience concepts, risk framing (to climate change impacts) and performance management into built asset management (maintenance and refurbishment) planning.

Practical implications - The paper concludes with a 10 step process developed as an aide memoir to guide social landlords through the climate change adaptation planning process.

Keywords: Adaptation, Built Asset Management, Housing, Risk, Resilience.

1. Introduction

The world's climate is changing in ways that will have a significant impact on both human society and the built environment (IPCC, 2014a). These changes affect not only average temperature but also results in changed temperature patterns and in particular the severity and frequency of extreme weather events (ibid). Whilst the impact of climate change is different across the world it is urban centres that are likely to be at greatest risk and where action needs to be taken to improve resilience to climate change threats (IPCC, 2014b). To this end in addition to mitigation measures actions that accelerate adaptation of the built environment are required (ibid). In particular actions are needed that reduce the vulnerability and improve the resilience of urban systems (e.g. housing, buildings and infrastructure etc.) and provide the governance, policies and incentives to realise adaptive capacity (ibid).

Building on the previous work and publication by Jones et al (2013) on the risk based adaptation framework, this paper reports the development of a staged process of including climate change adaption into built asset strategy for social housing in London.

The participatory action research project integrated the adaptation framework with built asset management theory and tested the resulting model against approximately 4000 housing units belonging to a social housing association in London. The paper concludes with a 10 step approach to adaptation planning that should allow Facilities Manager's in social housing sector to develop built asset management plans in order to improve the resilience of their built assets in face of climate change impacts on their building stock.

2. Background

Planning and design guidance (CLG, 2007; CLG, 2009; Environment Agency, 2009) to accommodate impacts of changing climate in the UK are well established but the same instruments are not universally applied to existing buildings. Since many existing buildings could be vulnerable to the impacts of climate change, and particularly extreme weather events (EWEs), adaptation measures will need to be implemented if they are to remain viable (Saunders & Phillipson, 2003).

Further, in the UK adaptation to climate change is not generally considered part of routine maintenance/refurbishment and it is unclear whether the macro level approaches used by the climate change community (UK climate projections, risk frameworks) can be effectively integrated specifically with existing built asset management models. These issues are particularly acute in London where a significant impact of changing climate is observed, which undermines the ability of existing social housing to provide the quality environment expected by residents (Jones et al, 2013). This poses a problem for many landlords and facilities managers who are faced with dilemma of prioritising adaptation for an uncertain future climate over solutions that improve the immediate quality of their housing stock today.

2.1 The Framework

The EPSRC Community Resilience to Extreme Weather (CREW) project studied the potential impact that a range of extreme weather events could have on the vulnerability, resilience and adaptive capacity of buildings in the SE London Resilience zone (Hallet, 2013). The CREW project used the UKCP09 weather files to project weather patterns for 2020 and 2050 across SE London and then superimposed these onto topographical and drainage information to identify relevant overheating and flooding impact scenarios. The scenarios were then used to investigate the risks to housing stock in the region and to identify adaptation solutions that could reduce vulnerability and improve resilience.

One of the key outputs from the CREW project was a risk based adaptation framework (Fig. 1), that sought to guide facilities managers through the climate change adaptation assessment process. The framework uses climate change scenarios to project the amount of change (impact) over current building(s) conditions that could occur. For each potential impact a risk assessment is then performed to identify possible adaptations and their relative cost. These adaptations are then prioritised or integrated into contingency plans (Jones et al, 2013). The action research project presented in the paper implements this framework to develop a staged process in order develop a built asset strategy which delivers the required performance in presence of future climate change impacts.

Inset Figure 1: Adaptation Framework (Hallett, 2013)

Since climate change impacts will affect the future performance of the built asset, in order to develop a comprehensive built asset management plan it is necessary to integrate the proposed adaptation framework with performance based built asset management approach rather than a condition based built asset strategy largely in use today.

To this end the key stages of performance based model proposed by Jones and Sharp (2007) (Fig. 2) is considered. The model involves following stages:

a) Identifying the critical success factors (CSF's) against which maintenance and refurbishment (including climate change adaptation) will be judged;
b) Measure the performance-in-use of each property;
c) Establishing the underlying cause of any underperformance;
d) Developing action statements that describe the required improvements in performance;
e) Developing and evaluating adaptation solutions against the organisations CSF's; and
f) Evaluating the success of the adaptations and provide feedback to the organisation's climate change adaptation policy and strategies.

The action research adopts the key components of the adaptation framework (Jones et al 2013) and applies them to the stages of the performance based model (Jones and Shrap 2007). The following sections presents the process stages of the action research and discusses the outcome with final concluding comments.

Insert Figure 2: Performance Based Built Asset Management Model (Jones and Sharp, 2007)

3. Methodology

3.1 The Method

Citing Lewin et al (1939), Gustavesen (2001) presents action research as expressing theory in a way that the experimental results can directly be fed into theory. In order to test and express the proposed process stages mentioned in fig 2 in practice the study undertook a series of facilitated workshops and semi-structured interviews at specific stages of

1) Policy strategy
2) Identifying needs

In addition building surveys of archetype housing units (undertaken by the RSLs consultants using standard UK guidelines), building simulation models and life cycle costing analyses were used to fulfil the stages of

1) Establishing cause and
2) Developing action statements

The final stage of formulating climate change adaptation inclusive built asset strategy was completed through discussions and meetings with research professionals and the facilities professionals of the social housing associations. The final discussions and results in turn feeds back to the proposed framework and suggests further work.

3.2 The Stock

The focus of the project was a UK Registered Social Landlord (RSL) that owns and manages approximately 4000 homes, located mainly in inner London. The RSLs property portfolio was extremely diverse, ranging from large modern purpose built blocks, to Victorian street properties. Majority of the RSL stock (86%) was made up of maisonettes and flats (conversion of houses rather than purpose built blocks) with few ownership of entire semi-detached or detached properties. From this 46% of the stock were bedsits or one bedroom properties, 33% were two bedroom properties; 18% were three bedroom properties; and the remaining 3% were 4 and 5 bedroom properties. In terms of age of the stock majority (49%) of the stock was built before 1919; 8% between 1919 and 1944; 22% between 1945 and 1980; and 21% post 1980. A number of RSLs properties were Listed Buildings and other were in Conservation Areas.

At the time of the project the majority of the stock was in a reasonable state of repair, with the RSL spending approximately £11m per year on maintenance/refurbishment and a further £25m on new build. The RSL had an asset management database, including condition survey of their stock, and had maintenance/refurbishment plans in place for general improvements over a 5 and 10 year period. A detailed contingency plans to deal with flooding events was present at the time of the project which accounted for flooding projection based on past climate data i.e. did not consider the future flooding probability based on climate change projections.

Considering the extensive and varied RSL stock in order to guide the action research and accounting for logistical reasons the fieldwork was limited to a sample of the RSL's housing, of 1255 properties or 31.46% of their total stock, located across London Borough.
The field work for the project took place in 2012/13. Although the project examined both flooding and overheating for the sake of brevity only the flooding results are presented here.

4. The process and the Results

The following section describes the process that the participatory action research to implement the stages outlined in fig 2.

Step 1 - Identify Policy/Strategy Drivers: The first task was to establish the Critical Success Factors (CSFs) against which current and future performance would be judged. This was done through discussion and workshops with senior managers and by reference to the RSLs strategic plan and operational documents. The RSLs approach to the quality of their housing was governed by their 'Performance Standard' that described expectations for the quality of the stock. Although the Standard didn't explicitly address the impact of climate change on the property, it did establish the general principle that:

"Your home should be in good working order and fit for purpose - it should meet a certain set of standards, both inside and outside and in shared and private areas to make it a safe and healthy environment to live in."

The Standard and discussions also revealed that the RSL would adopt a proactive approach ensuring the homes meet the Standard. To this end the 'Standard' provided the basis from which CSF's were derived and against which the success of adaptation solutions would be measured. For flooding these were:

1) Reduce disruption to tenants from flooding events. Performance thresholds to relate to the degree of disruption that a flood event would cause to tenants.

2) To continue to maintain tenant confidence and trust in the RSLs ability to deal with climate change issues. Performance thresholds to be measured through the tenant satisfaction survey. Once the CSFs had been established the next stage guided the identification of adaptation needs.

Step 2 - Identify Need: In order to identify the adaptation need there were three steps fulfilled resolving the questions

a) Which properties need to be adapted,
b) What is the level of vulnerability of the properties to flooding against which the adaptation is required and
c) The time scale required to implement adaptation measures

Noting the resources available to the RSL for flood risk assessment, the level of technical knowledge of housing stock management staff the existing flood maps and publicly available information was used.

The first question resolved by identifying the properties that were located in a potential (current and future) flood zone and were vulnerable to water ingress short listed. This was achieved by superimposing the RSLs properties across different London borough's onto existing flood maps using geo-referenced data and a geographical information system to identify those properties that were at potential risk of flooding. The flood maps at time of the study took account of climate change at level indicated by environmental agency guidance but did not provide any detail analysis in terms of depth of water ingress and surface water flooding taking account of sewage overflow. This limited the property level detailed analysis of flood impact. In light of this each property was then examined in more detail (using the RSLs asset management database, Google Street View, and external street surveys) to identify the potential for water ingress assuming a 0.5m flood in the street immediately adjacent to the property.

The second question was resolved by establishing the level of vulnerability for identified properties by combining potential flood risk and likelihood of water ingress into the property (Fig. 3).

To fulfil the last question it was necessary to combine the vulnerability and coping capacity of the selected at risk properties. The process used

a) Assessment of the potential impact of flooding events on a sample of properties identified as vulnerable was used to identify their coping capacity.
b) A combination of the potential damage that a flood event would cause and the recovery time it would take to return the property to its pre-flood performance level

was used to categorise the properties coping capacity threshold as Low Medium or High.

Insert Figure 3: Typical vulnerability threshold matrix for flooding

A resilience matrix (Fig 4) was developed by plotting the vulnerability and coping capacity for each identified 'at risk' of flooding property. Based on this matrix following was classified

i) Properties identified as highly vulnerable with a low coping capacity were prioritized for early action in the asset management plan.
ii) Those properties that were highly vulnerable but had a Medium/Low coping capacity would be prioritized as short-medium term action in the asset management plan.
iii) Properties that had a low vulnerability and high coping capacity would be reviewed at regular intervals as more climate change data became available.

Step 3 & 4 - Establish Cause and develop an action statement: Internal surveys of 26 typical properties were undertaken to establish the root cause of flooding damage and to identify potential adaptation solutions. In all cases these solutions were affected by legacy design decisions made when the buildings were newly constructed or underwent major refurbishments.

Adaptation options in the form of resistance (preventing water entering the property) and resilience (increasing speed of recovery once the property has flooded) measures were considered for each surveyed property. Based on the survey assessments it was established that it would be very difficult to resist the water ingress into basement flats or basement floors of individual houses.

Further, once water had entered the property it was likely to cause significant damage to both building components and fixtures & fittings that would require significant work in order to return the property to a habitable condition. Thus the best adaptation strategy for this type of property would be to allow the property to flood but to improve the resilience of building components (non-structural) and fixtures & fittings to shorten the time it would take to return the property to a habitable condition. Similar analyses were undertaken for ground floor flats, houses and communal areas and a set adaptation principles (Fig 5) were developed in the form of an ***Action Statement (Step 4)***.

Insert Fig 4: resilience matrix for flood risk properties

Insert Figure 5: Adaptation principles

Step 5- Develop Solutions: The potential (technical and cost/benefit) for a wide range of flood resistance and resilience measures were assessed for each archetype property. A set of triggers and thresholds were developed to allow potential adaptations to be prioritised for inclusion into the built asset management plan.

At the strategic level these triggers and thresholds tended to be statements of intent or desire, rather than quantified metrics to instigate an action. These statements of intent were related directly to the RSLs 'Performance Standard' and were expressed as commitments for each quadrant of the Impact/Priority Matrix shown in Fig. 4 and summarized in Table 1.

In addition to the generic triggers and thresholds outlined above, specific action were planned for Year 1 of the adaptation plan to address known, current problems. Where the problems are known, but the scale is unknown, action were set to be taken in the first 5 years of the adaptation plan to allow data collection for quantification of the scale of the problem. Where there is uncertainty about the potential problem or a solution the situation should be regularly monitored. A list of these thresholds and triggers are summarized in Table 2. Once all the previous described steps had been completed an adaptation strategy was developed to address the potential impact of flooding both today, and in the future. The strategy selected the adaptation measures based on the property typology, the level of vulnerability and the time scale of actions based on the triggers identified.

Insert Table 1: Action trigger/thresholds for flooding adaptations

Insert Table 2: Thresholds and triggers for action in an adaptation plan.

5. Discussion

This project sought to test the theoretical adaption framework developed through the CREW project by formulating a staged process that could be used to integrate it into a performance based built asset management planning model. Through this process a new 10 point action plan for adaption planning for future climate change was developed which is summarised in Table 3.

Insert Table 3: Ten step adaptation planning model

Whilst the theories supporting the adaptation framework and the performance based built asset management complemented each other at the theoretical level, a number of issues highlighted below were identified that limited its practical application.

1) Whilst the flood maps had included the future climate changes as per the environment agency guidance it lacked the detailed future risk assessments (level of flood water ingress at micro (property) levels). In addition the maps did not address the flood risk due to combine surface and sewer flooding scenario which is a major cause of property flooding in case of heavy rainfall event at micro level.

   Whilst the flood maps worked well when introducing the problem and examining the generic vulnerability and resilience of the housing stock (see Jones et al, 2013 for further details), it is noted that more work could be done to avail the detail flood risk data (level of flooding at local/property level) to build asset managers at reasonable cost and keeping in mind their technical ability to analyse such data.

2) Although the toolkits developed to assess the impact of flooding (and overheating) on a range of archetypal properties worked well, allowing 'potentially at risk' properties to be clearly identified and generic adaptation solutions to be evaluated, the level of

data required was significantly greater than that which existed within the RSLs built asset management database (step 4). A re-survey work (internal and external) had to be undertaken to identify the potential impacts that flooding (and overheating) would have on the performance of a range of property archetypes before indicative adaptation solutions could be identified and evaluated (step 5). Going forward the additional data needed for adaptation to climate change should be gathered as part of the routine stock condition survey process.

3) Whilst the RSL had a clear understanding of its performance criteria through its 'Performance Standard' translating this into generic adaptation principles (step 6) and strategic level thresholds that trigger inclusion of an adaptation into their built asset management plans (step 7) was more complicated than had originally been considered. For example the RSL had a number of basement flats that were at risk from pluvial flooding. Whilst the initial approach to adaptation (from the performance standard) was to make these properties resistant to flooding, it became clear through the study that such adaptations would be uneconomical to achieve. A compromise threshold was agreed for these properties to allow them to flood but improve their resilience to speed up recovery.

   Initially the RSL were very concerned that this approach would be interpreted by tenants as a 'don't care' attitude (contrary to the Performance Standard Principles) and they added a non-technical adaptation to work closely with tenants in the potentially 'at risk' properties to explain how they will support tenants through a flooding event. This included working with tenants to help them develop personal flood plans; providing support to allow tenants to protect valuable items; and having robust relocation plans in place.

4) The other problem with setting meaningful priority thresholds (step 7) and developing adaptation plans (steps 8 and 9) was the lack of specific quantifiable impact data and the numerous gaps in building data, which meant that only the most obvious adaptations were prioritised for action with the vast majority of adaptations being put 'on hold' until better information is available or until the future risk became obvious. In light of this the adaptation strategy can best be described as cautious and reactionary, which sits at odds with the need to accelerate adaptation of the existing built environment (IPCC, 2014b).

6. Conclusions

This project sought to integrate a theoretical adaptation framework with a performance based built asset management model to provide an approach by which Facilities Managers could develop short, medium and long term climate change adaptation plans. The project has described the process of identifying potential impacts of climate change on the performance of a house and how triggers and thresholds based on an organisation's CSFs can be used to prioritise interventions as part of routine maintenance and refurbishment planning.

Whilst the underlying theory and the assessment process developed in the project worked well, some of the data required to support the process was lacking or incomplete. This required, working assumptions to be made, which in turn reduced the level of confidence that Facilities Managers had in the final adaptation plans.

At the time of this project there was no consistent UK wide data on the future impact that climate change could have on physical performance of the building stock. Most flood maps that were available although considered climate change in their flood assessment, they didn't map future projections onto combine surface and local drainage topology and level of ingress at micro level. In addition to this the organisations asset management databases generally do not contain the level of building detail required to develop adaptation solutions. Whilst these issues do not undermine the development of the adaptation strategy, they will influence attitudes towards adaptation planning, resulting in a wait and see approach which is at odds with the needs to plan for the implications of climate change.

Better national and organisational data sets are needed to address this shortcoming. Finally, whilst the technical approach described in this paper worked well, it was developed within a mature organisation that had previously assessed its vulnerability, resilience and adaptive capacity to respond to potential climate change threats (see Jones et al, 2013). The approach may not be as easy to replicate for organisations who have not gone through this process. Also, it should always be remembered that it is people who are ultimately affected by the impacts of climate change and more work does need to be done to understand the factors that affect an individual's vulnerability and resilience. In this study no account was taken of vulnerable people living in houses with very low coping capacity.

7. Acknowledgements

Refer to the file titled 'Acknowledgements'

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TABLES

Table 1: Action trigger/thresholds for flooding adaptations

Resilience Quadrant	**Action Trigger/Threshold**
High Vulnerability / Low Coping Capacity	Take action to improve resistance and/or resilience over the next 5 years.
High Vulnerability / High Coping Capacity	Take action to improve resistance and/or resilience between years 6 and 10.
Low Vulnerability / Low Coping Capacity	Take action to improve resistance and/or resilience between years 11 and 30.
Low Vulnerability / High Coping Capacity	Take no action.

Table 2: Thresholds and triggers for action in an adaptation plan.

Year to Action	**Threshold**	**Trigger**
1	Know scale of problem and solution	Known level of risk is high
2-5	Know problem exists but don't know scale or solution	Establish level of risk
6-30	Unsure if problem exists. Don't have a solution	Continue to monitor risk

Table 3: Ten step adaptation planning model

Step		**Action**
1	Identify current climate related threats to your stock	Examine local histories for details of climate related impacts. Review national and local climate risk assessments (e.g. flood maps) and identify previous extreme weather events that have affected the region where properties are based.
2	Specify future climate impacts relevant to your circumstances	Identify future climate change impact for your area. Review national climate change assessments where they exist and undertake absolute climate change assessments where possible. In most cases individual organisations will not have access to the resources necessary to undertake absolute assessments so relative (step-up or morphing) assessments can be used as an alternative.
3	Map current and future climate threats to your property portfolio	Examine known vulnerabilities of your stock to the key climate change impacts. This would include geo-mapping the location of each of your properties onto

		current and future climate change risk maps (e.g. flooding, overheating etc.) and identify properties at risk and the level of the risk (e.g. flood type, flood depth, flood duration etc.) for each property, review the ability of existing disaster planning to cope with any increased incidence of extreme weather events.
4	Identify the coping capacity of your properties to current and future climate threats	Assess the impact that a climate related event would have on your property portfolio. Identify property archetypes for climate change events (flood impact assessments, overheating etc.) ensuring that the organisation have the data (either in their asset management system or through housing surveys) to assess the vulnerability and coping capacity of the property to each event. Develop organisation specific vulnerability and coping capacity thresholds for each property archetype against each climate change impact. Plot vulnerability and coping capacity onto a Resilience Matrix.
5	Identify possible adaptation solutions	Identify appropriate resistant and resilience measures. This will include modelling the effect of adaptation options against each archetype for each climate change impact and assessing the technical feasibility of retrofitting adaptation measures.
6	Articulate required improvements to the performance of your properties	Identify performance expectations for your properties against each climate change impact.
7	Identify priorities	Develop priority thresholds based on the performance expectations identified in step 6. Identify what types of adaptation should occur in short, medium and long term.
8	Develop adaptation strategy	Identify the actions to be taken for each vulnerable property archetype. This could include identifying known problems for immediate action in short term; gathering missing data (surveys) for high risk properties; and monitor performance of medium risk properties. All other missing data should be collected as a part of the normal resurvey cycle.
9	Prepare adaptation plan	Identify individual properties requiring action in short term (steps 3, 4 and 8). This will involve detailed (property level) assessments of the potential for different adaptation solutions identified in step 5 to achieve the performance improvements identified in step 6. Use priority thresholds (step 7) to order adaptation actions. Cost each solution and select appropriate ones for inclusion in the adaptation plan. Develop an adaptation programme for the works.
10	Implement and test plan	Monitor effectiveness of interventions and close the feedback loop. If you experience a climate related event

		how well did your plans work? If you don't experience an event then test your plans against a simulation. Review the effectiveness of your Disaster Management and Contingency Plans

FIGURES

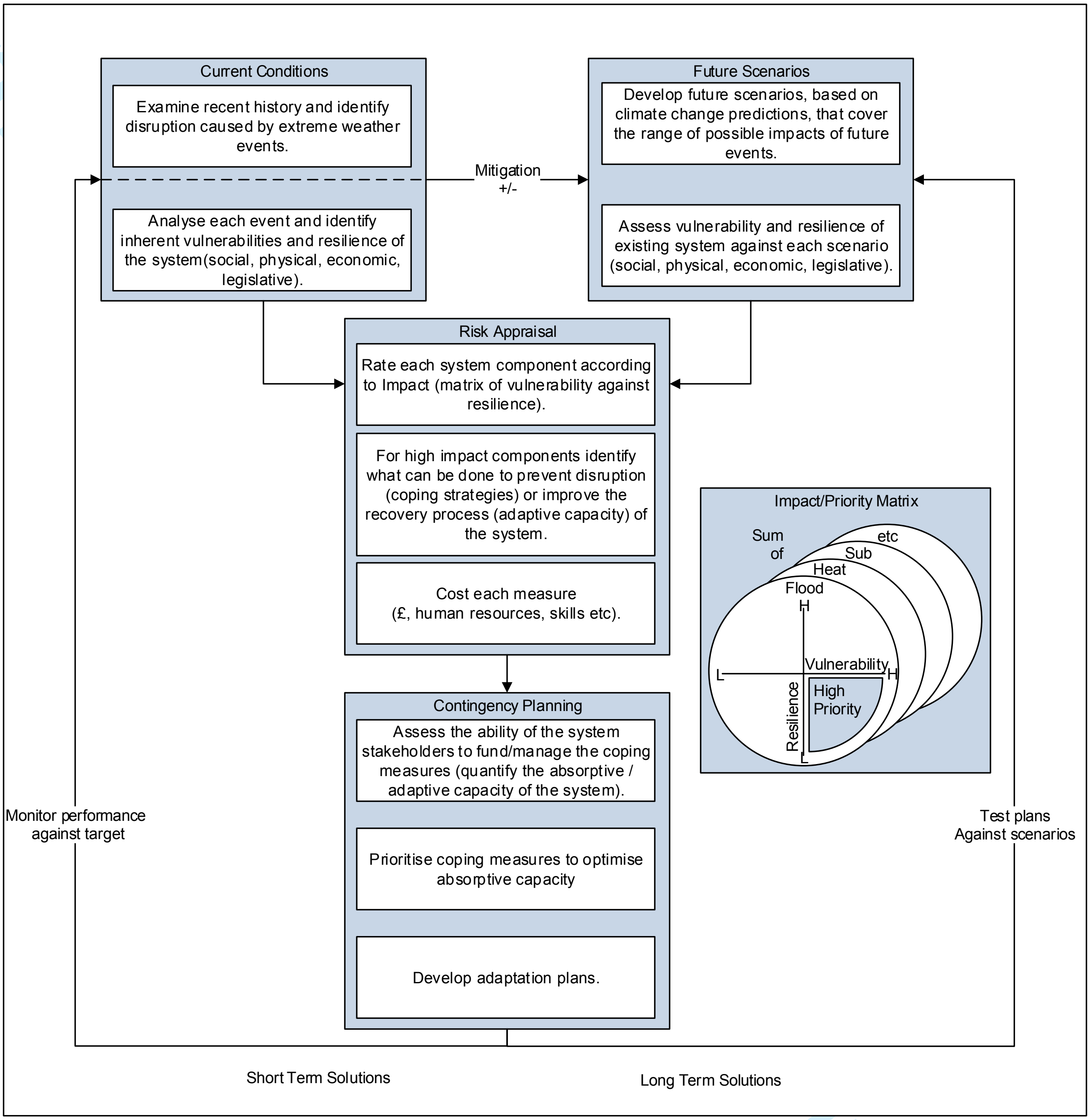


Figure 1: Adaptation Framework (Hallett, 2013)

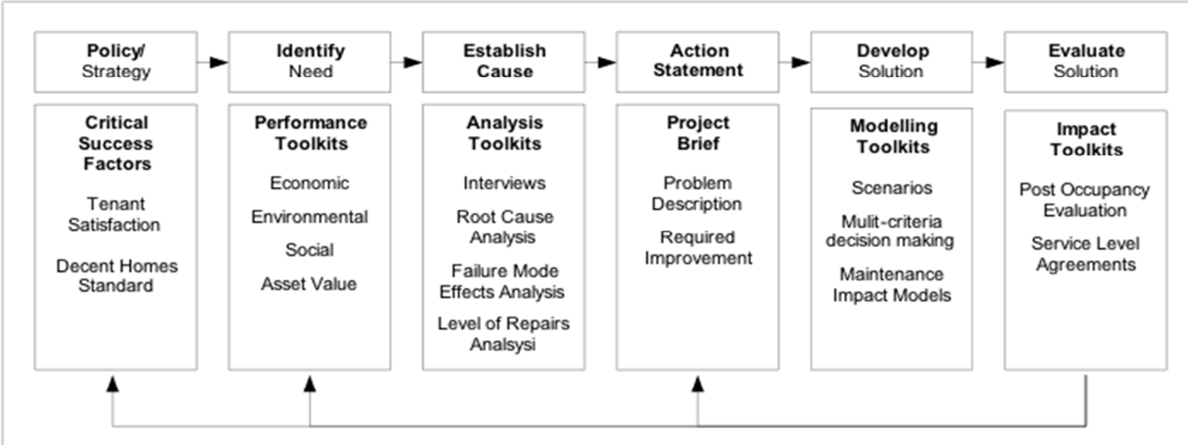
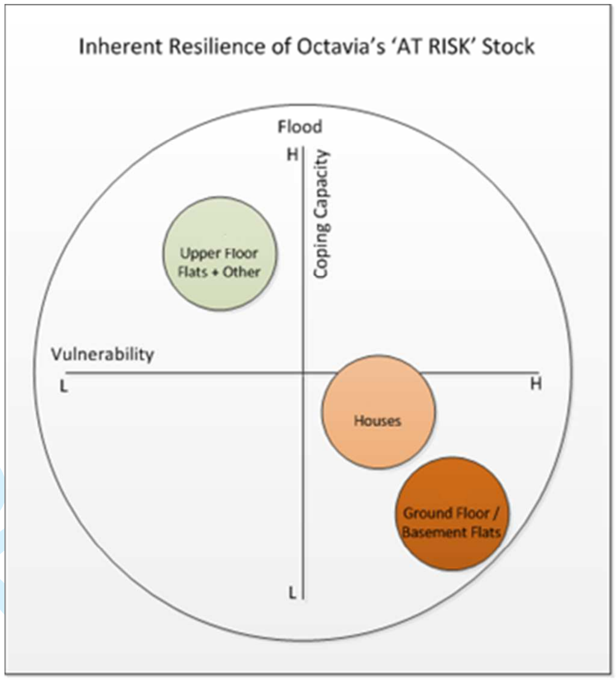


Figure 2: Performance Based Built Asset Management Model (Jones and Sharp, 2007)

		Likelihood of a flood event			
		No likelihood	Low	Medium	High
Likelihood of water ingress to the property / damage to critical infrastructure	No likelihood	Not vulnerable	Not vulnerable	Not vulnerable	Not vulnerable
	Low	Not vulnerable	Low vulnerability	Low vulnerability	Low vulnerability
	Medium	Not vulnerable	Low vulnerability	Medium vulnerability	Medium vulnerability
	High	Not vulnerable	Low vulnerability	Medium vulnerability	High vulnerability

Figure 3: Typical vulnerability threshold matrix for flooding



Adaptation Guiding Principles

- If it is economically feasible to prevent flood water entering a property than this should be adapted.
- Water resilient components, fixtures and fittings should be installed when flood ingress is likely.
- Ensure all essential services are resistant to a flood event.
- Work with residents to prepare personal flood action plans

Fig 4: resilience matrix for flood risk properties

Figure 5: Adaptation principles